

DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

Research and Development
Requirements of the
Shipbuilding and Marine
Engineering Industries

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PREFACE

THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH have asked their Economics Committee to carry out on their behalf a series of studies of the research and development needs of important industries in the United Kingdom. The purpose of these studies, which are made with the collaboration of the industries concerned, is to help the Council to allocate the resources for research and development which the Government puts at their disposal so as to achieve the maximum benefit to the national economy. But the Council's resources are only a small part of the national total and, since far more money and effort is spent by industry itself, the Council hope that, by publishing the results of these studies where possible, a wider purpose may be served.

This report on the research and development needs of the shipbuilding and marine engineering industries has been discussed with the Shipbuilding Conference, as representing those industries, and is published with their concurrence. The recommendations have been agreed between the Shipbuilding Conference, the Ministry of Transport and the Department of Scientific and Industrial Research, and the industries' collaboration in their implementation is assured.

8th December, 1960

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Research and Development Requirements of the Shipbuilding and Marine Engineering Industries

I. INTRODUCTION

1. WORLD shipbuilding capacity is far in excess of foreseeable demand for some years ahead. The British shipbuilding industry is facing very severe competition for available orders. The evidence suggests that British shipbuilders may have to adjust themselves to some contraction of production during the next few years despite the fact that the prospects for the economy as a whole are of increasing prosperity.

2. The first part of this paper describes the economic situation which has arisen, and makes some tentative estimates of the trend of world production and trade in ships over the next few years, as a background for the consideration of the longer term research and development needs of the industry. There follows a discussion of the United Kingdom industry in which a certain amount of evidence is cited which suggests that production costs are generally too high to ensure that United Kingdom yards can compete successfully with the best foreign yards. Even if this is true it is not a cause of the present situation, but it is likely to become an increasingly serious matter as orders become more scarce, and if not rectified it will prevent the British industry from retaining its share of the market when demand eventually improves.

II. THE WORLD POSITION

3. World launchings of merchant ships rose from 3.64 million gross tons in 1951 to a peak of 9.27 million gross tons in 1958, by which time world fleets had grown to 103.8 million gross tons.⁽¹⁾ In 1957 a severe slump in freight rates occurred, which continued throughout 1958 and 1959; by October 1959 nearly 9 million gross tons of shipping were laid up, while order books fell from a peak of over 35 million gross tons in 1957 to about 22½ million gross tons at the beginning of 1960.

4. World shipbuilding capacity continued to expand up to 1959, as new facilities planned in earlier years came into production, so that the peak demand for shipbuilding was already past before peak building capacity became available. By 1959 capacity was estimated at about 11 million gross tons, already a significant excess over world launchings at 8.7 million gross tons.

5. The important factors influencing the demand for new ships are the age and obsolescence of existing fleets and the growth in the volume of sea-borne trade. The life of a ship is normally at least twenty years. Between 1951 and 1957 the volume of dry-cargo trade increased by 41.7 per

⁽¹⁾ All figures in this Report relating to the world fleet are exclusive of the U.S. Reserve Fleet.

cent, but, owing largely to the increasing speed and efficiency of new ships, shipping in service increased by only 21·8 per cent. By July 1960 the total available world merchant fleet (excluding the United States reserve fleet) was estimated at 108 million gross tons (of which about 5½ million gross tons was laid up). It is, therefore, quite obvious that, given the increased efficiency of new ships, replacement at between 3 and 5 per cent per annum, and the growth of tonnage in service at the recent rate of about 3½ per cent per annum (required to meet the growth of sea-borne trade), cannot create a sufficient demand for new tonnage to employ more than some half to two-thirds of the world's shipbuilding capacity (which is sufficient to replace the whole of the present world fleet in ten years). Until laid up shipping is either called back into service or scrapped, demand can be expected to fall even lower.

6. In 1958 the world's shipbuilding industries launched a total of 9·3 million gross tons of new ships. The total for 1959 was 8·7 million and the 1960 figure is likely to be about 8·3 million. Projections of the trend of production must take into account such factors as the rate at which laid up tonnage will be brought back into service, the rate of scrapping of old ships and the expansion of world sea-borne trade. Estimates based on reasonable assumptions about these factors, in conditions of normal supply and demand, suggest that world production during the next five years could fall to as low as a quarter of the present level before it begins to recover.

III. THE UNITED KINGDOM POSITION

7. In 1959 the United Kingdom shipbuilding industry included some 80 shipyards (owned by some 70 companies) capable of building ships over 100 gross tons, a number of specialist concerns engaged in marine engineering or shiprepairing, and in addition several hundred small firms mainly engaged in boat building and repairing and other ancillary activities. In 1958 only 30 shipyards had an output, in terms of new ships launched, of over 20 thousand gross tons.⁽¹⁾ According to estimates based on the preliminary results of the Census of Production for 1958, the turnover of the shipbuilding and shiprepairing industries (excluding the Royal Dockyards) was about £370 million in that year. This figure includes some duplication which arises through intermediate transfers of goods and services within the industry. The turnover of the separate marine engineering firms was about £82 million but most of their output was sold to the shipbuilding industry and is therefore included in the £370 million given above. The net output⁽²⁾ of the shipbuilding, shiprepairing and marine engineering industries as a whole was about £200 million.

8. Although it has been claimed that with its present facilities, the shipbuilding industry is capable of an output of 1·75 million gross tons of merchant ships per annum, it has not, in fact, achieved this output

⁽¹⁾ In the same year only 27 yards completed over 20 000 g.t. of new ships: Shipbuilding Conference.

⁽²⁾ Net output is the value of goods and services produced less the value of materials (including bought-in components) and fuel used.

in any year since the war, although until quite recently order books have been full, and even "over-full". The causes are variously attributed to steel shortages, to shortages of various types of skilled labour and to lost time for a variety of reasons, including strikes. Gross tonnage figures, of course, take no account of the different types of ships built. United Kingdom production is made up of a great variety of different types including naval ships and a proportion higher than any other country of passenger liners and specialized types which demand more time and labour to complete and command a correspondingly higher price. However between 1951 and 1959, tankers, cargo liners, and tramps (including bulk ore carriers) accounted for 87 per cent of gross tonnage of total launchings of merchant ships and never fell below 83 per cent in any one year.

9. Table I shows United Kingdom and world tonnage launched for the years 1951-1959.

TABLE I
Tonnage of ships launched

	United Kingdom	World	United Kingdom share
	(million gr.t.)	(million gr.t.)	(per cent)
1951	1.34	3.64	36.8
1952	1.30	4.39	29.6
1953	1.32	5.09	25.9
1954	1.41	5.25	26.8
1955	1.47	5.31	27.7
1956	1.38	6.67	20.7
1957	1.41	8.50	16.6
1958	1.40	9.27	15.1
1959	1.37	8.74	15.7

Source: Lloyd's Register of Shipping.

It is apparent from these figures that if the United Kingdom industry had entered the lists to retain its 1951 share of world output, it would have needed to double its capacity, in order to produce well over three million gross tons per annum. It is pointed out by the industry that this would have added still further to the disparity between world capacity and world requirements; though, of course, capacity in other countries might not have increased so much if it had been possible for British yards to expand so as to offer earlier delivery dates. The post-war rehabilitation of shipbuilding capacity overseas, particularly in Germany and Japan, and the re-entry of these ex-enemy countries into the market for ships must inevitably have resulted in a reduction of the United Kingdom's share of total world production. Nevertheless it is relevant to note that in the period 1951-59 Sweden, Holland, France, U.S.A., Denmark, Belgium and Norway (as well as Germany and Japan) all nearly or more than doubled their output. In 1938, the United Kingdom's share of world production was 34 per cent; by 1959 it was less than 16 per cent; Japan's share rose from 15 to 20 per cent and Germany's is still only 14 per cent compared with 16 per cent in 1938.

10. The investment policies of the United Kingdom shipbuilding industry have been aimed at modernization and re-equipment rather than at expansion of capacity. Between 1951 and 1956 gross investment in the

shipbuilding, shiprepairing and marine engineering industries (excluding the Royal Dockyards) averaged £8 million per year, representing between 2 and 3 per cent of turnover or $4\frac{1}{2}$ per cent of net output.⁽¹⁾ In 1957 gross investment was estimated at £14 million and in 1958 at £18½ million (excluding the Royal Dockyards) representing 5 per cent of turnover or $9\frac{1}{2}$ per cent of net output in that year. Investment is expected to continue at or above this level until 1961 when the current modernization plans of most yards are expected to be complete. The lower rate of investment up to 1956 is partly explained by the fact that there has been no significant expansion of production facilities, and partly by the fact that investment in modernization has had to be undertaken alongside current production during a period when every effort has been strained to maintain full output. Also, up till 1955, investment was generally under central control both financially and through steel allocation. Insofar as investment programmes have involved the introduction of entirely new methods, they have called for radical changes in labour organization and in the phasing of work. Under pressure for maximum production and in the prevailing climate of labour relations these changes could not be made quickly or easily.

11. There has been a very large investment overseas in entirely new (or, in the case of ex-enemy countries, entirely reconstructed) yards, in which neither proximity to current production, nor traditional attitudes to production methods and to labour/management relations, have retarded or deterred the introduction of the very latest plant and techniques. These new facilities are particularly evident in Japan, Western Germany and Sweden, whose combined production in 1959 accounted for 43 per cent of the world total. There are few figures available to compare the rate of investment in foreign countries with that in the United Kingdom, but in Norway investment averaged about 6 per cent of turnover between 1952 and 1956.

12. The existence of surplus shipbuilding capacity will make competition for orders increasingly keen. It can be expected that more foreign governments will take steps to secure the orders of their own shipping industries for their own yards, even if they do not go further and provide subsidies to enable their shipbuilders to tender for foreign orders below cost. Even under fair competition the United Kingdom's position is threatened by some highly efficient new yards abroad, particularly in Sweden and Germany, whose productive capacity is certainly in excess of the orders they are likely to receive from shipowners of their own nationalities. United Kingdom yards are now quoting shorter delivery dates than a year ago, and fixed prices instead of the escalator clauses upon which they have hitherto insisted. Profit margins have clearly been slashed. But in spite of all efforts total new orders received in 1959 (including export orders) were only 319 000 gross tons, nearly two-thirds of which were secured in the last quarter.

13. Ships launched by United Kingdom yards for foreign registration fell from 45 per cent of total launchings in 1951 to 8 per cent in 1959. In the same period the United Kingdom share of the world export market in ships (ships built for registration in countries other than the country

⁽¹⁾ See footnote (2) on page 2.

of building) fell steadily from 49 per cent to 3 per cent. By 1959 the United Kingdom had become a net importer⁽⁴⁾ of ships: ships launched in the United Kingdom for foreign registration totalled 115 000 gross tons; ships launched abroad for United Kingdom registration totalled 449 000 gross tons, of which 387 000 gross tons were tankers ordered for the large oil companies under conditions of abnormal demand.

14. On the basis of the present order book, United Kingdom launchings in 1960 may exceed 1.4 million tons; the effect on production of the falling off of orders will begin to be felt in 1961. Demand from British owners, assuming that they maintain their share of world carrying trade, may normally average between 0.9 and 1.0 million gross tons a year after 1962, but the effect of laid-up tonnage and other factors on ordering may well cause output to fall below this level in the next few years. In order to maintain output at the present level, United Kingdom shipbuilders would need to secure all available orders from United Kingdom shipowners and, in addition, to attract an average of between 400 000 and 500 000 gross tons of foreign orders per annum. To do the latter would mean increasing the United Kingdom's share (now 3 per cent) of world exports. The effect of excess building capacity overseas will no doubt stimulate nationalistic policies (measures to retain the orders of national fleets for domestic yards). It is likely, therefore, that the volume of orders available for international competition will shrink more rapidly than total demand. An estimate based on the calculation of the world trend and taking nationalistic policies into account, suggests that the total volume of "export" orders may average about 1.5 million gross tons a year over the next five years, though it could be much lower in any one year. The United Kingdom industry would need to secure a third of the market to maintain the present level of output.

IV. COSTS AND PRODUCTIVITY

15. Discussions with shipowners and other interested people, both British and foreign, have produced much evidence that the quality of British ship construction is satisfactory, but that prices have tended to be too high for tankers and general cargo vessels in which foreign yards compete most strongly. It is very difficult to collect reliable evidence on comparative costs as between one shipbuilder and another, more particularly as between shipbuilders in different countries. This is partly because firms in a highly competitive industry are naturally unwilling to advertise their true position either to their competitors or to their customers; but partly it is because of the widely varying methods of cost calculation. There is, however, an amount of evidence which taken together tends to confirm that British shipbuilding costs have recently been high by comparison with those of major competitors.

16. Some evidence can be adduced from prices which are generally known. Over a period prices must have a close relation to costs or shipbuilders would not remain in business. Evidence collected by the industry

⁽⁴⁾ Imports in terms of launchings are of course timed differently from imports in terms of the arrivals of newly purchased ships (which are given in the trade statistics).

about tenders in 1958 and 1959 suggests that British quotations could be anything from 10 to 40 per cent higher than the lowest foreign quotation. Shipbuilding employers used this evidence to emphasize to the unions that something must be done to solve the industry's labour problems. Recent announcements by shipbuilders who have secured orders against foreign competition show that they are having to quote prices related to bare cost with no expectation of profit and even, in some cases, making only part allowance for overheads. These same firms are known to be leading the industry in the introduction of cost-cutting techniques and methods.

17. An attempt has been made below to examine the evidence on costs. For this purpose the costs of a ship are divided into the costs of raw materials and bought-in components, over the prices of which the industry has little or no influence, and the costs of labour and overheads which are more directly within the industry's control. Raw materials and bought-in components normally account for rather more than half the cost of a ship, direct labour and overheads for rather less than half.⁽¹⁾ Table II indicates the rather favourable position of the United Kingdom *vis-à-vis* her major competitors in regard to the steel used in shipbuilding in 1959 and 1960.

TABLE II
*Comparison of domestic prices of open hearth steel in certain countries at
31st December 1959 and 1st November 1960*

Material	Ships plates P.403 20 ft. x 6 ft. x $\frac{1}{2}$ in. (Price per ton for 25 ton lots)		Angles basic quality 5 in. x 5 in. x $\frac{1}{2}$ in. (Price per ton for 50 ton lots)	
	31st December 1959	1st November 1960	31st December 1959	1st November 1960
Dates at which prices were in force	£ s. d.	£ s. d.	£ s. d.	£ s. d.
United Kingdom... ..	45 5 0	44 15 0	39 5 0	38 5 0
United States	51 1 0	51 1 0	52 5 0	52 5 0
West Germany	53 3 0	53 3 0	42 16 0	42 16 0
France	52 14 0	55 6 6	38 11 0	40 5 0
Holland	48 16 6	48 16 6	38 11 0	40 5 0
Italy	64 11 0	64 11 0	42 8 0	42 8 6
Japan*	52 8 0	48 7 9	44 7 0	41 6 6

Sources: Iron and Steel Board.

* Basic price quoted by Japanese Iron and Steel Federation.

Raw material prices are entirely outside the control of the industry, but both design and production methods can affect material cost as a proportion of total cost, and economies which resulted in reduced weight or more efficient material usage could increase the United Kingdom's existing advantages. In the case of bought-in components it has been suggested that the industry could take greater advantage of the possibilities of standardizing its requirements. This is worth continued investigation.

⁽¹⁾ A typical analysis of the costs of a dry cargo vessel of 6000 gross tons is:—

	Per cent
Raw materials	34.5
Bought-in components	22.0
Direct labour	23.5
Overheads	20.0
	100.0

As components and fittings are often specified by owners, their co-operation would have to be enlisted, but the initiative in introducing standardization must normally come from the manufacturer, not the customer, by offer of appropriate price reductions for standard products.

18. It is difficult to compare the remuneration of labour between one country and another: statistics are usually compiled on different bases and the incidence of over-time, social insurance and other charges varies. The available information, however, indicates that in terms of total earnings per man hour worked in 1959, labour was about 20 per cent cheaper in Germany and 45 per cent cheaper in Japan than it was in the United Kingdom, while in Sweden it was about 40 per cent dearer.

19. The latest information available suggests that some United Kingdom shipyards are undoubtedly holding their own in competition for the small number of orders available, but the fact that Sweden is also able to secure a share of orders suggests that the Swedish industry is able to offset its higher direct costs in labour and materials by a substantially higher productivity. The findings of the team sent in 1959 by the industry to visit Swedish shipyards should provide valuable evidence on this point. It is to be hoped that they will be made generally available. It would be interesting to know which of the different techniques employed by foreign yards are giving them greatest advantage.

20. While there are no official figures for productivity in the ship-building industry, a general indication of trend is given by the figures for work done in terms of gross tonnage per person employed in construction. Between 1946 and 1959, the work done per person employed was consistently within 2½ per cent of 22 tons per person per year; in 1948 it was 21·7 gross tons per person and the average for the three years 1957-59 was 21·9 gross tons per person. These averages have been weighted to take account of changes in the composition of output in terms of types of ships constructed; they do not allow for the fact that the complexity of most types of ships has increased over the period. This last factor cannot be demonstrated by calculations based on gross tonnage constructed. There is, however, no evidence to suggest that, over the industry as a whole, labour productivity has significantly increased, in spite of increased investment in production plant and machinery (see paragraph 10, p. 3).

21. It is also significant that average construction times⁽¹⁾ (from start of work to completion) in months during the period 1957-59 were: United Kingdom 19, Germany 10, Sweden 9, Japan 8.⁽²⁾ These large differences cannot be explained entirely by reference to differences in the types of ship constructed in the different countries; nor can they be explained by a lesser need for speed in United Kingdom yards, because it must be assumed that shipbuilders, who during this period had full order books, would have been anxious to vacate berths as quickly as possible. Shortages of steel may have had some effect at the beginning of the period. Although building times in some yards have shortened in recent months, it seems certain that the fullest use of shipyard space and capital equipment is handicapped by labour conditions and by the impracticability of shift

(1) Weighted by tonnage of ships launched.

(2) Source: *Lloyd's Register of Shipping*.

working, which operates in a number of other countries. This is clearly a factor contributing to the lower productivity of British yards indicated in the preceding paragraphs.

V. QUALIFIED STAFF

22. The Advisory Council on Scientific Policy has published estimates of the distribution of qualified scientists and engineers based on a survey carried out by the Ministry of Labour in the first week of January 1959. Table III reproduces their estimates for the shipbuilding, shiprepairing and marine engineering industries (excluding the Royal Dockyards).

TABLE III
Estimated numbers of scientists and engineers in the shipbuilding and marine engineering industries

	Total	Shipbuilding and Ship-repairing	Marine Engineering
<i>Graduates or equivalent</i>			
Chemists	7	1	6
Mathematicians	9	5	4
Physicists	6	1	5
Metallurgists	14	—	14
Chemical engineers	5	—	5
Civil and structural engineers	20	16	4
Electrical engineers	39	22	17
Mechanical and other engineers	1108	482	626
B.Sc. (Tech.)	32	31	1
Total graduates	1240	558	682
<i>Holders of H.N.C. or H.N.D. only</i> ...	957	395	562
<i>Total qualified</i>	2197	953	1244

Source: Scientific and Engineering Manpower in Great Britain 1959 (Cmd. 902).

Unfortunately both naval architects and marine engineers are included in the group called "mechanical and other engineers" but it is reasonable to suppose that the majority of the 482 engineers in this group employed in the shipbuilding and repairing industries are naval architects and the majority of the 626 in marine engineering are marine engineers. The industries have traditionally laid emphasis on qualifications in naval architecture, marine engineering and other fields, and firms have encouraged and helped their young entrants to acquire them.

23. The total employment in the combined industries in Great Britain in November 1958 was estimated at 193 500 of whom 165 600 were operatives and 27 900 "other employees".⁽¹⁾ These latter included management, supervision, design and drawing office staff as well as office staff. Comparison of the estimates for total qualified staff employed in merchant shipyards and marine engineering (2197) with that for total "other employees" of all kinds (27 900) gives a ratio of about one qualified scientist or engineer to about 13 other non-operatives. This is a fairly normal

⁽¹⁾ Statistics of employment in this paragraph are taken from Ministry of Labour returns and exclude employment in the Royal Dockyards and in small boat and yacht building and repair firms.

ratio in engineering industry. The ratio of qualified staff to the total number of employees of all grades in shipbuilding and marine engineering is about 1:88. The greater concentration of qualified men in marine engineering is illustrated by the separate figures for this section of the industry. In November 1958 total employment was estimated at 61 000 of whom about 49 300 were operatives and about 11 700 "other employees". The ratio of qualified scientists and engineers to "other employees" was about 1:9½ and to total employment, 1:49. The equivalent ratios for shipbuilding and repairing without marine engineering were 1:17 and 1:139.

VI. RESEARCH AND DEVELOPMENT

24. Of the total of 1240 scientists and engineers with graduate or equivalent qualifications, 247 were estimated to be employed mainly on research and development, 47 in shipbuilding and 200 in marine engineering. About half the latter were employed in two establishments run by shipbuilding firms for the Admiralty and may be considered to be employed mainly on Admiralty work.

25. The D.S.I.R. enquiry on costs of research and development indicated that the cost of employing a fully qualified scientist or engineer on research and development associated with shipbuilding and marine engineering (including the cost of providing supporting staff) was about £6000 per annum.⁽¹⁾ Using this figure, expenditure on research and development in the shipbuilding industry in 1958 appears to have been about £282 000 and in marine engineering about £1 200 000—or a total of about £1·5 million for the combined industries. At this level expenditure on research and development was 1·0 per cent of net output in shipbuilding and marine engineering (not including shiprepairing) compared with 2·6 per cent for manufacturing industry as a whole (excluding aircraft) and 1·8 per cent for non-electrical engineering industry as a whole.⁽²⁾

26. The estimated expenditures on research and development in the foregoing paragraph do not include the contributions made by the industries to co-operative research. In 1958 the British Shipbuilding Research Association (BSRA) received £281 000 from the industry and £50 000 from D.S.I.R., and spent £277 000. The Parsons and Marine Engineering Turbine Research and Development Association (PAMETRADA) received £264 000 from its member firms, £70 000 from D.S.I.R. and £75 000 from Admiralty, and spent £568 000.⁽³⁾ In addition the Shipbuilding Conference made a

⁽¹⁾ Based on figures supplied in confidence by firms in the industry as the result of a questionnaire on research and development expenditure in 1958 sent out to manufacturing companies by D.S.I.R. in April 1959. The results of the D.S.I.R. enquiry were published as *Industrial Research and Development Expenditure, 1958*, H.M.S.O., 1s. 3d.

⁽²⁾ Allowance should, however, be made for the fact that in shipbuilding and marine engineering development work is not represented by the construction of prototypes and pilot plant, which figure largely in the development costs of other industries. New design features and new production techniques are tried out in current production, and the additional costs of design time as well as any production failures are normally treated as production costs. On a very rough estimate, fair allowance for these costs might add at least another £1 million to the industry's research and development expenditure.

⁽³⁾ In 1958 PAMETRADA received an additional £125 000 from the Shipbuilding Conference for "capital development".

grant of £3000 to the British Welding Research Association. The cost of the Ship Division of the National Physical Laboratory of the Department of Scientific and Industrial Research was £234 000, of which £20 000 was provided by shipbuilders in the form of fees for tests and £8500 by BSRA. Taking industry and government together, therefore, total expenditure on research in and for the industry was probably of the order of £2.5 million, which is about 1.7 per cent of net output. This is below the average "burden" carried by the other engineering industries. The major part of the research effort was, however, in the field of marine engineering. On the above figures (expenditure in the industry itself plus the expenditure of PAMETRADA and half the expenditure of BSRA), expenditure on marine engineering research and development appears to have been about £1.9 million or about 4.4 per cent of net output, a figure which compares favourably with most other manufacturing industries. Unfortunately it is not possible to compare British effort in this field with that of any of the major competitors in Europe.

27. Shipbuilding is to a large extent an "assembly" industry and benefits from technological advances in many other industries which supply materials, components and production plant. The above figures take no account of the research which has contributed to these advances, or which may do so in the future. In particular, almost all the research which is currently being done on nuclear reactors for ships is being done outside the industry. The actual amount in terms of money which the shipbuilding industry itself spends on research is not necessarily a guide either to its technological progress or to its own assessment of the need for such progress. As an assembly industry its contribution to the costs of development of the items it assembles will normally be included in the price it pays. There remain, however, two fields in which expenditure must reflect the industry's assessment of its problems: design and production methods.

28. Naval architecture has an ancient and honourable place in British engineering traditions. The senior management, as well as design and production staff, in shipbuilding firms are normally qualified naval architects. It is not, therefore, surprising that the main emphasis of research has been on design and on factors associated with quality—i.e. efficient and reliable performance. The work of the National Physical Laboratory Ship Division is devoted to the hydrodynamic problems associated with the design of ships' hulls and propellers. Its test facilities are in constant demand by shipbuilders, which is in itself evidence of the importance the industry attaches to improvement of performance through advances in design. Within the industry, three shipbuilding yards own towing tanks in which they carry out hydrodynamic studies. Through their membership of the Shipbuilding Conference, shipbuilders also belong to the British Shipbuilding Research Association, whose work is again largely concerned with design and with the quality, safety, convenience and efficiency of ships' performance.

29. As regards advances in production technology as such, shipbuilders have shown their willingness to adopt new developments when the advantages of doing so have been clear. The introduction of welding to replace riveting is probably the most important example. On behalf of the industry the British Welding Research Association undertook the

development of heavy welding applications for shipbuilding, and further work on the continuous welding of vertical seams has been under discussion. Another example is the flame cutting of ships' plates, a technique now used in a number of yards both in the United Kingdom and on the Continent. In connection with the further use of computers, British Oxygen Gases Ltd., and Ferranti Ltd., are developing a computer controlled flame cutting machine which will automatically control the cutting of steel plates from information recorded on a tape. The first two machines will be installed in two British shipyards very soon. The development of this technique will, if successful and where it can be applied, eliminate the cumbersome manual templating in the mould loft, as well as improving the accuracy of cutting. The rate at which further development can take place depends to a large extent upon co-operation within the industry, but in this development the British industry has an opportunity to gain an important technical lead.

30. While United Kingdom yards are alert to new technical possibilities, many have, for one reason or another, been slow to re-organize their production methods to reap the full benefit of advances in technique. Many shipyards have employed production engineering consultants to advise them on production layouts and programmes, but the implementation of such advice has frequently resulted in labour upsets, which, in a period of full order books, may have made the industry as a whole reluctant to use the results of such investigations. None of the research organizations serving the industry has hitherto included in its programme any major investigations designed to improve or cheapen production methods. The recent setting up of an organization to look into this, and the appointment of appropriate staff to BSRA, are welcomed. It is to be hoped that the proposed studies will include not only methods of hull construction, but also methods for improving the efficiency of the fitting out of ships.

VII. MARINE ENGINEERING

31. Twenty-two shipyards have main engine works. Of these, 17 make boilers, 14 steam turbines, 15 diesel engines and 5 gearing. In addition to the shipbuilders there are a number of firms building main propulsion units but not ships. There are three large boiler designers and about fifteen other firms prepared to supply marine main boilers, mostly built under licence from either Babcock and Wilcox Ltd. or Foster Wheeler and Company Ltd. There are also about 20 marine diesel manufacturers, many supplying only small and medium-sized diesels, 5 marine turbine builders and 3 marine gearing specialists outside the shipbuilding industry.

32. In all there are about 35 separate engine building units supplying engines to, on average, about 160 ships a year of over 1000 gross tons. Smaller ships (less than 1000 gross tons) are usually powered by diesel engines manufactured by the "land" diesel engine specialists. The small scale production prevalent in the marine engineering industry is still further underlined by the fact that, in 1959, 18 turbine building firms supplied turbines to 33 ships totaling 585 000 horse power—an average of 32 500 h.p.

and less than 2 sets per firm. In 1958 only four firms built over 90 000 h.p. taking turbines and diesels together. The situation in this country is in marked contrast to that in U.S.A., Germany, Japan, Sweden and Denmark, where production is concentrated in a few large manufacturing units.

33. For all practical purposes at the present time the choice of propulsion machinery for ships is between steam turbine or diesel. Table IV analyses United Kingdom launchings between 1954 and 1959 by the type of propulsion machinery selected.

TABLE IV
Analysis of U.K. launchings by type of propulsion machinery installed
(ships of over 100 g.t.)

	Steam Turbine*		Diesel†	
	Number of Ships	'000 gross tons	Number of Ships	'000 gross tons
1954	54	643.6	163	714.0
1955	48	645.7	196	776.6
1956	53	718.5	204	648.8
1957	39	564.2	210	837.5
1958	32	495.0	243	903.0
1959	25	459.6	243	907.0

Source: Lloyd's Register of Shipping.

* Includes a small number of steam reciprocating with exhaust turbine and turbo-electric installations.

† Includes a small number of diesel electric installations.

Recent years have shown a continuation of the trend in favour of diesel installations. (Steam reciprocating engines are now of trivial importance and are therefore omitted from Table IV.) A more detailed analysis of 1959 launchings by size of ship shows that ships up to 10 000 gross tons almost all had diesel engines; four-fifths of the ships between 10 000 and 20 000 gross tons had diesels; 86 per cent of ships over 20 000 gross tons had turbines.

34. In the lower power ranges the advantages of the diesel engine over the turbine are its lower capital cost and lower fuel consumption. Turbine installations become relatively cheaper as the power required increases, their maintenance costs are lower than the equivalent diesel installations and they have a higher power/weight ratio. The net advantages of the diesel engine thus diminish as power requirements increase, and in passenger ships the greater vibrations set up by the reciprocating action of the diesel engine are a disadvantage from the point of view of passenger comfort.

35. In the smaller power ranges, marine diesels are supplied by a number of well-established firms, who make diesel engines for a variety of other applications. These firms do a considerable amount of research and development on their own, many support the British Internal Combustion Engine Research Association (BICERA), and, since their exports are large, they can be regarded as being in a fairly strong competitive position. In the larger power ranges, however (over about 5000 horse power) there is only one independent British designer, Wm. Doxford & Sons (Engineers)

Ltd., although Harland and Wolff Ltd., who manufacture under licence from the Danish firm of Burmeister and Wain, are primarily responsible for the design of the opposed piston type engine which they sell as the "Harland-B. and W." engine. Large marine diesels are built by shipbuilding firms or marine diesel specialists under licence from either Doxford, Harland and Wolff or foreign designers. Many builders hold more than one licence. Between 1950 and 1959 the proportion of large marine diesels built to foreign designs increased from 25 to 46 per cent, and all the eleven principal Doxford licensees are also licensees of foreign designers. At least five new foreign licences have been taken out in the last three years largely because of the increasing interest in diesel engines of powers above 10 000 h.p.

36. Until recently the only practicable form of propulsion for very large ships (mostly tankers) was the steam turbine. Now diesel engines are available up to 20 000 to 25 000 horse power. They have been developed by large continental firms, notably Burmeister and Wain (Denmark), Fiat (Italy), Gotaverken (Sweden), M.A.N. (Germany) and Sulzer (Switzerland). Several ships are already at sea powered by engines up to 20 000 h.p. Although both Doxford and Harland and Wolff have announced that they have designed engines of powers up to 18 000 to 20 000 h.p. neither has yet built such an engine or received an order for one.⁽¹⁾

There is no doubt that continental designers have led the way in this field. The firms in question are large-scale producers and support relatively large research and development teams. The reasons for the British position are probably on the one hand that no British marine diesel designer has a large enough production to support research or development on a sufficient scale, and on the other hand that available resources have been concentrated on medium size-range engines for which there is and likely to be a larger demand. Even if the basic research were done by BSRA, BICERA or otherwise the problem of finance for development would remain. This may well be a field for government civil development contracts.

37. Marine turbines for merchant ships are made in the United Kingdom by seventeen firms, nearly all of which are shipbuilders, and by A.E.I. Ltd. All except A.E.I. Ltd. are members of PAMETRADA, which acts as their design centre as well as carrying out research and development on their behalf. The big turbine manufacturing groups such as A.E.I. Ltd., English Electric Ltd., and C. A. Parsons, Ltd. are not members of this Association. English Electric Ltd. applied for membership of PAMETRADA in 1947 and their application was rejected on the grounds that they were not a "marine" firm (although they had in fact built marine sets during the war). Subsequently (1951) C. A. Parsons Ltd., who had been founder members of PAMETRADA, resigned their membership. Representations were made to the Association both by Admiralty and D.S.I.R. to broaden the basis of their membership, and in 1957 the Association suggested to English Electric, A.E.I., C. A. Parsons and G.E.C., and also

⁽¹⁾ Wm. Doxford and Sons (Engineers) Ltd. have recently decided to build their large engine and to test it on their test bed. This development will cost the company some £750 000.

to General Electric and Westinghouse of U.S.A., an arrangement for exchange of information and also offered the use of its full scale test facilities (then the only ones in the United Kingdom) under safe-guards of confidentiality. These offers were declined. In effect until quite recently shipowners have had no real alternative in the United Kingdom to PAMETRADA designs for steam turbine powered ships. Until 1944 the Navy relied exclusively on the "marine" firms, but since then have widened their field by having turbines for warships designed by A.E.I. and English Electric which, for the most part, have been built under licence by the traditional marine firms.

38. The formation of PAMETRADA in 1944 was an obvious solution to some of the problems of the small firms, who could not afford to support adequate research and design teams of their own. At the time it was probably the only solution. The "land" firms had neither the design nor the production resources to divert to the marine field, and ship-building demand could not have been met without the production capacity of the "marine" industry. There are, however, several schools of thought on the merits of this solution. On the one hand claims are made on behalf of PAMETRADA that its designs are the best available, and that the turbine installations produced by its members are as good in service as those of any of their (foreign) competitors.⁽¹⁾ On the other hand critics of PAMETRADA maintain that the designed performance and the record in service of foreign turbines are superior, and that the big turbine firms like A.E.I. Ltd. and English Electric Ltd. should be encouraged to enter the marine field, so that the benefits of their very considerable research and development could be available to counter foreign competition. The evidence in support of these varying points of view is conflicting. However, the existence of criticism among shipowners, whether well-founded or not, is important, and there may be a case for an impartial investigation.

39. In competition with large-scale producers, the small producer either has to support higher overhead costs per unit of production, or else is unable to keep pace with advances in production techniques, or both. Some design overheads are, of course, shared through membership of PAMETRADA, and other overheads are to some extent shared with other engineering activities. No reliable cost comparisons are available, and again conflicting claims are made.

40. The relationship between PAMETRADA and its members is different in one major respect from the normal relationship between designer and licensee. PAMETRADA does the basis design for its members who themselves do the detailed design and produce their own working drawings. PAMETRADA exercises no control over the detailed design and has no powers to inspect production. Normal licensing arrangements, such as some marine engineering firms have now made with either A.E.I. Ltd. or English Electric Ltd. or with foreign designers, provide the licensee with the complete design including working tolerances. Licence agreements prohibit the licensee from altering the licensor's design without his consent and give the licensor the right to inspect production.

⁽¹⁾ Up to September 1960, 5.8 million h.p. of turbines to PAMETRADA basis designs had been completed.

41. It is in the interests of shipowners to demand the best that industry can supply, and not to restrict their search for better products to their traditional suppliers. The larger shipping companies employ qualified staff to advise them on specifications and on the choice of propulsion systems; but it is not generally the custom of the United Kingdom shipping industry to use the services of consultants—a practice which is common in the U.S.A. and some other countries, and, indeed, in other industries in the United Kingdom. There may well be scope for an independent expert consultancy service in this country to advise shipowners on the design, performance and efficiency of alternative propulsion systems.

42. The Admiralty have set up such an organization in the form of the Yarrow-Admiralty Research Department (Y-ARD). This organization is run for the Admiralty by Yarrow and Co. Ltd., shipbuilders. Yarrow and Co. are members of the warship group of shipbuilders and are important builders of frigates and destroyers for the Navy. When the company accepted the responsibility for running Y-ARD they gave up designing boilers for warships in recognition of the principle that Y-ARD should be independent of any financial interest in design. The Department is now staffed by about 60 qualified engineers and scientists, all of them employees of Yarrow and Co. The Department carries out investigations into installation design on behalf of the Admiralty, writes the specifications for warship machinery, and generally acts as Technical Consultant to the Admiralty on Marine Propulsion. On several recent occasions the Admiralty has allowed Y-ARD to perform similar services for merchant shipowners. Y-ARD might be able to accommodate additional merchant work, though if the demand became heavy it might be better to form a second organization rather than to enlarge Y-ARD much beyond its present size. It is possible that while Y-ARD is regarded as an Admiralty affair, shipowners may be shy of asking for its services; but if it were to become an independent consultancy organization supported by fees, the attitude might change very quickly. There certainly appears to be a strong case for this or some similar organization to serve the interests of the British merchant marine.

VIII. PROPULSION DEVELOPMENT

43. In the field of nuclear propulsion an important step forward has recently been taken by the Minister of Transport, who has invited tenders for a 20 000 shaft horse power propulsion installation based on either of the two reactor systems selected by the Galbraith Committee as being worthy of special attention. The Yarrow-Admiralty Research Department is acting as consultant to the Ministry of Transport, and with other authorities will render assistance in the examination of the tenders received. The results of this examination should define the present technical and economic possibilities for nuclear propulsion as far as they can be defined without building a ship. The indications are, however, that nuclear propulsion, or, more accurately, the use of fissionable material as boiler fuel in a turbine

installation, is a very long way from becoming an economic alternative to conventional systems in ordinary merchant ships. It was, however, largely at the instigation of the Shipbuilding Industry that serious attention was turned to the use of nuclear power for merchant marine purposes, and through teams at Risley and Winfrith, BSRA is assisting in development in this field.

44. Meanwhile there would seem to be scope for the further development of conventional systems. The fragmentation of the production of the numerous components of complete marine propulsion units has certainly been one of the factors retarding development. The isolation of important parts of the industry from the makers of prime movers for other applications has also contributed to this state of affairs. As far as diesels are concerned, the marine diesel designers have special problems in that there are no other applications for very large slow-running diesels. It is of interest that Mr. T. W. D. Abell in his Presidential Address on 12th October, 1960, to the Institute of Marine Engineers (Scottish Section) suggested that to meet foreign competition, marine engineering firms should be grouped in a limited number of combines and should standardize their products. He envisaged for Clyde-side, for instance, one big engineering concern which would operate a number of factories in which engine manufacture would be concentrated on particular types.

45. Another interesting development is the free piston engine, that is to say, a free piston gasifier delivering gas to a turbine which drives the shaft. This engine was originally developed in France, and all the further development has been in the hands of licensees and sub-licensees of the inventor. In the United Kingdom there is one licensee, and there are nine sub-licensees, of whom four are shipbuilders. At the present stage of its development, the free piston engine has a much lower fuel consumption than a marine gas turbine burning fuel in a combustion chamber attached to the turbine. The fuel consumption is still higher than that of operational diesel installations; but on the other hand the free piston engine shows promise of good maintenance characteristics even on residual oils, and it is free from the vibration disadvantages of the diesel engine referred to in paragraph 34. Recent British installations are encouraging and a further development effort, aimed at improved performance, certainly seems justified.

46. Other lines of development of the gas turbine may in the long run be important. Since the experimental gas turbine installation in the Shell tanker AURIS little work has been done in this field. Work has been carried out by PAMETRADA for Admiralty on liquid cooled blading but Admiralty support has been withdrawn as a result of cuts in defence expenditure and of a realization that, even if the project were proved technically feasible, the gains in relation to complexity (*vis-à-vis* an air-cooled turbine) would not be sufficiently rewarding for naval purposes. There is, however, a strong case for pursuing investigations for merchant marine purposes, preferably in association with the aero-engine industry, which has hitherto done most of the research in this field. The investigations should include the possibilities of burning heavy fuel in gas turbines and the metallurgical problems associated with running at very high temperatures. The development of the high temperature gas cooled nuclear reactor for marine use will probably demand a gas turbine installation. In the

long term this could be a most promising field of marine propulsion development.

47. Although there is clearly a case for the continued development of the large slow-running single diesel engine, further work might also usefully be done on the development of multicoupled medium speed diesel installations. In the field of steam turbine development the research and development facilities of PAMETRADA can play an important part. The Association is currently building a prototype set of 22 000 h.p. designed for steam conditions in advance of present practice. This set is intended for full-scale testing on the Association's test bed. The building of their own prototype is a new venture which should produce valuable results.

48. The shipbuilding industry is currently reviewing the functions of PAMETRADA and BSRA (which is responsible for research in fields of marine engineering other than turbines). Possibly some new formal arrangements for co-ordinating research will be suggested by this review. Such arrangements must surely include adequate participation by ship-owners, whose future performance requirements must be taken into consideration and whose experience must be the final arbiter of success. The evidence summarized in the foregoing section suggests that there is need for more detailed study of development possibilities in relation to the future needs of shipping. Strong and conflicting views are held on the relative merits of the various propulsion systems for the many different service requirements. Until a detailed technical and economic study has been made it will not be possible to formulate a co-ordinated policy for research and development covering the whole field, or to assess its contribution which ought to be made from public funds to ensure that both British shipping and British shipbuilding can maintain their lead over all competitors.

IX. CONCLUSIONS

(1) The world shipbuilding industry is facing a major and probably prolonged recession.

(2) There is no indication that the United Kingdom shipbuilding industry has on balance any marked technical or economic advantage over its major foreign competitors apart from its large home market.

(3) The total effort at present devoted to research and development in the field of shipbuilding and marine propulsion is insufficient in relation to the serious problems now facing the industry.

(4) In particular almost no organized research has hitherto been applied to the industry's production and management problems with the object of increasing the productivity of labour and capital and reducing costs.

(5) While adequate effort is probably being devoted to problems of hull resistance and propeller design, the development of propulsion installations is handicapped by the organizational structure of the industries producing propulsion units and auxiliaries and, in consequence, by the insufficient use of available research facilities.

X. RECOMMENDATIONS

It is recommended that,

(1) Further steps should be taken by D.S.I.R. and the Shipbuilding Industry in collaboration with the Ministry of Transport to examine the research and development needs of the industry as a whole and to review the arrangements for carrying out research.

(2) In view of the current examination by the industry of the organizations and programmes of the British Shipbuilding Research Association and PAMETRADA, arrangements should be made for a concurrent economic and technical study of research and development needs in the field of marine engineering to provide background for the Research Council's consideration of the reports they will receive from the two Associations.

(3) The study recommended in (2) above should be carried out by D.S.I.R. with the assistance of the Ministry of Transport and in close association with the two Research Associations and the Industry.

(4) In view of the great importance of research into production techniques and methods aimed at increasing productivity and reducing costs, D.S.I.R. and the Ministry of Transport should consider with the Industry what assistance could most appropriately be given to the industry's own efforts to promote such research.

(5) As an immediate stimulus to development D.S.I.R. should give priority consideration to proposals for development under contract in the shipbuilding and marine engineering industries.

(6) The Ministry of Transport and D.S.I.R. should consider with the Shipping Industry what further steps should be taken to study the industry's future technical requirements.